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Open innovation as the missing link in the mediated model among R&D educational heterogeneity, innovation and performance

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ABSTRACT

This study examines the interrelationships between the educational structure of the research and development (R&D) department, open innovation, innovativeness and organisational performance. The main purpose of the article is to help companies establish successful R&D as one of the determinants of organisational performance, and to explore the underlying processes and boundary conditions of this relationship. Based on the theoretical background of R&D management, cognitive diversity, and open innovation, we hypothesise that R&D educational heterogeneity is positively related to organisational performance via innovativeness, which is moderated by firms' open innovation. We collected data from 151 organisations based in Slovenia, Austria, and Croatia. We analysed the data with (moderated) mediation procedures. Our findings support the hypotheses, except for the direct relationship between R&D education heterogeneity and organisational performance, and confirm our expectations regarding the high importance of innovativeness as a mediator of this relationship. Furthermore, our findings are consistent with theoretical assumptions that group and R&D diversity and open innovation interplay in predicting innovativeness and ultimately firm performance. Our findings provide new perspectives on R&D, particularly on the educational structure of R&D employees and its interaction with open innovation in relation to organisational performance.

Introduction

European Union (EU) documents and policies emphasise the critical role of R&D in increasing prosperity and are recognised by policymakers (EC, 2020). R&D is in most cases the result of teamwork; successful collaboration within R&D requires skilled people with proper education (Østergaard et al., 2011). Literature focused on innovation in R&D indicates that the creation of new knowledge is associated with the ability to improvise (Vera et al., 2016), making it a sought after characteristic in R&D departments as well.

Successful problem-solving in R&D, as well as the overall performance of such departments, depends on the diverse experiences and knowledge of their members (Hoisl et al., 2017). Research has consistently demonstrated that both ethnic and educational heterogeneity within organisations can drive innovation (Mohammadi et al., 2017). Similarly, Parrotta et al. (2014) established a clear link between the educational and demographic diversity of organisational members and their ability to foster innovation. Furthermore, diversity across gender, race, ethnicity, and sexual orientation is positively associated with solving complex, non-routine problems (Phillips, 2014), whereas homogeneity tends to limit the range of opinions and problem-solving approaches (González-Moreno et al., 2018).

The desired heterogeneity can be cultivated effectively through open innovation (Chesbrough, 2003). Studies have shown that embracing open innovation can positively influence both the innovativeness and financial success of organisations (Faems et al., 2010). Yet, the relationship between diversity and innovation is not always straightforward. For example, Østergaard et al. (2011) found no clear connection between ethnic diversity and innovation. Instead, they discovered that organisations with diverse educational backgrounds among their employees were better equipped to absorb new knowledge and generate innovation. This highlights the importance of educational heterogeneity, particularly within R&D teams, in driving performance. However, the precise role of diversity in sparking innovation and boosting overall organisational outcomes remains less clear.

By examining educational heterogeneity in R&D, and further

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exploring its implications in the context of open innovation, this study provides a new perspective for research on successful R&D. This is important because this unique approach uncovers a new dimension of the interplay between heterogeneity in R&D and open innovation and links it to innovativeness and performance. It helps organisations build more innovative R&D teams and contributes to organisational performance.

Therefore, the purpose of this study is to help organisations build more successful R&D that can potentially contribute to organisational performance. The aim of this paper is to examine the factors in R&D and beyond that interplay in affecting a firm's performance. The first intended contribution of this study is related to developing a better understanding of how educational heterogeneity in R&D interplays with innovation in affecting organisational performance. While prior studies have shown that different types of heterogeneity are related to organisational innovativeness and performance (e.g., Díaz-García et al., 2013; Geroski et al., 1993; Grund & Westergaard-Nielsen, 2008; Herring, 2009; Østergaard et al., 2011; Rajapathirana & Hui, 2018), we complement this research by adding a new perspective on heterogeneity - educational heterogeneity. In this way, we seek to contribute to the R&D management literature and the organisational performance literature by providing a more detailed understanding of a specific conceptualisation of heterogeneity and innovation and the mechanisms of their relationship to organisational performance.

The second contribution of this paper relates to the exploration of a boundary condition of open innovation. Our focus is on the concept of open innovation, which has been shown to be positively associated with organisational innovativeness and performance (Cheng & Huizingh, 2014; Chesbrough, 2003; Enkel et al., 2009; Faems et al., 2010; Garriga et al., 2013; Laursen & Salter, 2006; Lettl et al., 2006; Parida et al., 2012; Piller & Walcher, 2006). We attempt to bridge these research streams by examining how the different types of innovation interact, and in particular, by complementing prior research with an examination of the moderating role of open innovation in the relationship between R&D heterogeneity and organisational performance through innovativeness. In doing so, this research provides a new perspective on diversity in R&D and (open) innovation, potentially leading to higher organisational performance and, in turn, greater prosperity.

Theory and hypotheses

Organisations typically pursue success by striving for efficiency in resource utilization. While a substantial body of literature exists on this subject, there has been limited exploration of the relationship between R&D educational heterogeneity, open innovation, and their combined influence on innovation and organisational performance. Educational background generally affects absorptive capacity (Cohen & Levinthal, 1990), leading to the assumption that the educational heterogeneity of an R&D team should increase the team's and thereby firms' absorptive capacity. Higher absorptive capacity is positively related to innovativeness, financial performance (Kostopoulos et al., 2011), and successful outside-in open innovation process (Vanhaverbeke et al., 2008).

In recent times, it has become increasingly important for organisations to measure and prioritize non-financial performance indicators (Zarzycka & Krasodomska, 2022). One of them is innovativeness (Hoffmann & Fieseler, 2012). Oztekin et al. (2015) investigated how knowledge management, non-financial performance, and financial performance indicators are related. They found a strong correlation between knowledge management quality and non-financial performance indicators. They also found a robust correlation between non-financial indicators and financial performance indicators. The direct correlation between knowledge management and financial performance indicators was weak. Thus, it is crucial to consider how we approach knowledge management and non-financial performance indicators within a company. By effectively integrating both knowledge management and non-financial performance indicators, we can achieve financial success.

The number of non-financial performance indicators in organisations' annual reports is increasing. In addition, some studies suggest that the importance of non-financial performance indicators will increase in the future. They are likely to increasingly influence the valuation of organisations in the stock markets (Arvidsson, 2011). How much attention is paid to non-financial performance indicators also depends on how good an organisation's financial performance is. Organisations that are more financially successful pay more attention to non-financial performance indicators on average than less successful organisations (Coram et al., 2011).

The size of an organisation also plays an important role in applying non-financial performance indicators (Ahmad & Zabri, 2016), and size is also potentially related to diversity (Arnegger et al., 2014). R&D in larger organizations can apply their ideas and innovations to a wider variety of products than smaller organizations, which results in lower marginal costs of R&D (Cohen & Klepper, 1996). Larger organisations often have more resources at their disposal, including the financial capacity to invest in systems and processes that capture and analyse non-financial data. Also, they are usually subject to greater public scrutiny and regulatory requirements, facing higher expectations from stakeholders, including investors, customers, employees, and the community, to demonstrate their commitment to social, environmental, and governance practices (Samuels et al., 2021). This external pressure incentivizes them to adopt and disclose non-financial performance indicators more rigorously. On a related note, larger organisations tend to have a more diverse workforce due to their broader operations and presence in multiple locations. This diversity can provide a more comprehensive understanding of various stakeholder needs, allowing these organisations to better identify and address relevant non-financial metrics such as employee engagement, community impact, and customer satisfaction.

Several authors have discovered a positive relationship between the diversity of R&D teams and an organisation's level of innovativeness. Reagans and Zuckerman (2001) state that R&D is more productive when employees are brought on these units across different time periods. Díaz-García et al. (2013) found a positive relationship between gender diversity of R&D employees and innovativeness. Hoisl et al. (2017) showed that R&D workforce diversity is desirable and has a positive impact on departmental performance. Niebuhr (2010) found that R&D workforce diversity in terms of knowledge, cultural background, and skills can lead to more successful R&D. Tang and Ye (2015) found that there is a strong and positive relationship between R&D employee knowledge diversity and creativity. Sun et al. (2017) found that diversity in the group has a positive impact on individual and group learning and that this is positively related to innovativeness.

Østergaard et al. (2011) state that educational heterogeneity in an organisation is important in absorbing and creation of new knowledge and innovativeness. Leal-Rodríguez et al. (2015) found that innovativeness is related to organisational performance. Geroski et al. (1993) found a positive correlation between an organisation's innovativeness and profitability. Similarly, Rajapathirana and Hui (2018) have concluded that innovativeness is positively related to an organisation's financial performance. Herring (2009) found that a diverse workforce in terms of race and gender is positively associated with higher total revenue and a higher share of net income.

Based on these facts, we propose hypotheses 1a, 1b, and 2, which refer to a relationship between educational heterogeneity, and organisational performance via organisational innovativeness (Díaz-García et al., 2013; Geroski et al., 1993; Herring, 2009; Hoisl et al., 2017; Niebuhr, 2010; Rajapathirana & Hui, 2018; Reagans & Zuckerman, 2001; Tang & Ye, 2015). Diverse educational backgrounds within R&D teams contribute significantly to the heterogeneous composition of team members, which enriches the cognitive diversity of the department. This cognitive diversity manifests through a range of skills, domain mastery, and different types of knowledge, all of which are directly linked to

increased levels of innovativeness (Dahlin et al., 2005; Østergaard et al., 2011). The presence of such heterogeneity allows team members to approach problems from multiple angles, drawing on varied academic experiences and knowledge frameworks. This diversity in perspectives enables faster, more effective problem-solving, a key factor in the success of R&D departments.

The ability to view problems from multiple perspectives is particularly valuable when addressing complex, non-routine challenges that require novel solutions. Research has shown that teams with diverse educational backgrounds are more likely to generate creative ideas, as they combine their unique knowledge sets to explore a wider range of potential solutions (Hundschell et al., 2022). The ability to quickly generate and evaluate different solutions can lead to more innovative outcomes, which is crucial for maintaining a competitive edge in rapidly evolving markets. Moreover, educational heterogeneity enhances the team's capacity to integrate and apply external knowledge, facilitating open innovation processes and helping organisations stay ahead of industry trends (Bogers et al., 2018).

Heterogeneity in R&D also reduces the risk of groupthink, a phenomenon where homogenous teams tend to conform to a single way of thinking, limiting the scope of potential solutions (Cox & Blake, 1991; Milliken et al., 2003). Intellectual diversity enables teams to be more likely to challenge assumptions, question established practices, and pursue unconventional ideas, all of which contribute to greater organisational innovativeness. In contrast, teams lacking diversity may struggle to break free from existing paradigms, leading to slower progress and less effective problem-solving.

However, the benefits of educational heterogeneity extend beyond just innovation and problem-solving speed. Teams with a heterogeneous mix of backgrounds are better positioned to understand and address the needs of a diverse customer base. In a globalised market, where consumer preferences and technological requirements vary widely, having a diverse R&D team ensures that solutions are tailored to a broad range of user needs (Makudza et al., 2020; Van Beers & Zand, 2014). This adaptability can lead to better product-market fit and improved customer satisfaction, further enhancing the organisation's overall performance.

The link between diverse education and organisational performance is further supported by studies that demonstrate how diversity in R&D teams enhances their ability to absorb and apply new knowledge (Østergaard et al., 2011). This capacity is particularly important in current fast-changing and complex markets, where technological advancements and scientific breakthroughs play a crucial role. The more diverse the educational backgrounds within the R&D team, the better equipped they are to synthesise external information, adapt to new technologies, and create innovative products and processes (El-Awad et al., 2017). As such, diversity not only fosters internal innovation but also amplifies the organisation's ability to leverage external knowledge sources, potentially driving firm performance. Thus, overall, on the arguments outlined above, we expect educational heterogeneity is positively related to firm performance via innovativeness, and propose the following three hypotheses:

H1a: Educational heterogeneity in R&D is positively related to organisational performance.

H1b: Educational heterogeneity in R&D is positively related to organisational innovativeness.

H2: Organisational innovativeness mediates the relationship between educational heterogeneity in R&D and performance.

Based on previous studies, we can assume that open innovation can leverage innovativeness to result in organisational (financial) performance. Nowadays, it is essential for many organisations to use open innovation because they cannot do everything within an organisation (Lichtenthaler, 2011). An organisation that uses the concept of open innovation increases incremental innovation performance rather than radical innovation performance (Garriga et al., 2013). Chesbrough (2003) found that organisations that use open innovation bring external knowledge and ideas into the organisation, which adds value. Lichtenthaler (2011) asserts that using the concept of open innovation is crucial for many organisations today because they cannot do everything within an organisation. Enkel et al. (2009) found that involving organisations from different industries in R&D is becoming increasingly important because it is the only way they can innovate successfully. Indeed, Garriga et al. (2013) found that the use of open innovation increases incremental innovation performance. West and Bogers (2014), found that organisations with robust internal R&D are less inclined to seek and use external technology and innovation.

On the other hand, Bogers et al. (2018) found that educational heterogeneity positively influences an organisation's ability to leverage external knowledge. In cases where internal diversity is lacking within R&D, open innovation offers a way to introduce diverse perspectives from outside, thus enhancing innovativeness. We assume that increasing heterogeneity within R&D will lead to greater innovation, as it enables problems to be viewed and solved in varied ways. Additionally, we propose that open innovation has a more significant impact on homogeneous R&D teams than on heterogeneous ones. In diverse R&D teams, employees are already likely to approach problems from different angles and solve them more quickly (Choi, 2007; Cox & Blake, 1991), meaning the added value of an external fresh perspective is relatively lower. We propose the following:

H3a: Open innovation interacts with educational heterogeneity in R&D in predicting organisational innovativeness. The relationship between open innovation and organisational innovativeness is more positive in case of educational homogeneity than educational heterogeneity in R&D.

Based on these arguments, we can assume that R&D heterogeneity in organisations that exhibit a high level of open innovation is positively related to the organisation's innovativeness and, consequently, to organisational performance. Applying the concept of open innovation allows educationally homogeneous R&D teams to consolidate their experiences when working with organisations that are not in the same field. It will affect more educationally homogeneous R&D teams than heterogeneous ones. By connecting externally, diverse R&D departments with different employee profiles of employees will be able to leverage and consolidate their different knowledge and experience.

At the same time, open innovation helps organisations solve their problems faster, more efficiently, and with lower costs (Cheng & Huizingh, 2014; Enkel et al., 2009). In this way, the different perspectives of heterogeneous R&D teams can be incorporated into firm-level innovation and thus into organisational performance (Enkel et al., 2009). Last but not least, Faems et al. (2010) found that open innovation is positively associated with innovativeness and firm performance. The logic of the next hypothesis is similar to hypothesis 3a, here we try to find out how the interaction between educational heterogeneity and open innovation is related to performance. Fig. 1 shows the entire model. This model is tested with the following hypothesis:

H3b: Open innovation moderates the relationship between educational heterogeneity in R&D and performance, mediated by innovativeness. When organisations have low educational heterogeneity in R&D, open innovation contributes to highest levels of performance.

Methodology

Data collection

The survey was sent via email, which included a URL link to the survey and an address where we defined the purpose and goal of the survey. The survey consisted of 15 questions or measurement scales. They related to general information about the organisation, such as industry, organisational structure, size, and age, as well as questions about R&D and innovation and the company's financial performance.

The questionnaire was prepared in Slovenian, Croatian, and German - back-translation procedures were used in translating the original scales

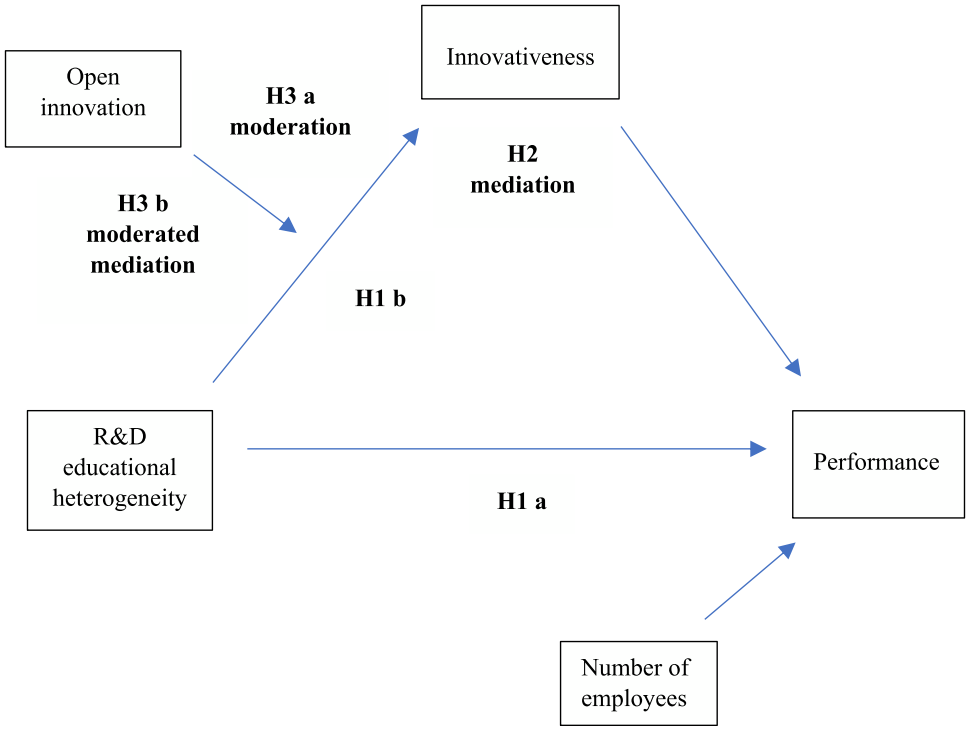

Fig. 1. Research model with hypotheses.

into each of these languages. We received contact information from organisations in Slovenia, Croatia, and Austria from the following databases: Aurelia (Austria), HGK (Croatia), and COBIK (Slovenia). In the case of Austria, we included all companies with >10 employees. For other countries, we did not impose any specific limitations due to the constraints of the contact dataset. We sent out 36,849 survey invitations in Austria, 11,299 in Croatia, and 1878 in Slovenia. In total, we sent 50,026 surveys to various organisations. The time frame for sending the research questionnaire lasted from November 23, 2017, to October 19, 2018. The sending process was carried out by first author via email. We received a total of 151 fully completed surveys reported by 1ka - an open source application for conducting online surveys. Of these, 53 are from Slovenia, 52 from Croatia and 46 from Austria..

Measures

Our independent variables are R&D educational heterogeneity, open innovation, and innovativeness. The dependent variable is performance, and the control variable is the size of an organisation.

R&D educational heterogeneity was assessed by one item, "In addition to engineers, masters and doctors of science (natural sciences), do you have employees with any other education in your R&D?" Such an approach has previously been used in studies of Dahlin et al. (2005), or Østergaard et al. (2011). Despite its simplicity, using a binary question represents a valid way to measure educational heterogeneity in R&D. The purpose of this question is to capture the basic presence of interdisciplinary perspectives, which can be sufficient for many research and practical purposes. By focusing on whether there is any diversity beyond the natural sciences, the question provides a straightforward and efficient way to identify organisations that engage a broader range of expertise. It serves as a useful starting point for understanding the composition of R&D teams without overwhelming respondents with detailed classifications, which might introduce complexity and potential confusion. Moreover, the binary nature allows for easy aggregation of data across firms or industries, providing a clear and scalable indicator for comparative analysis while still pointing towards the presence of educational heterogeneity in R&D activities.

Innovativeness was measured by items provided by Škerlavaj et al. (2010), ***and open innovation*** was measured using the items from Rangus et al. (2016) – these scales can be found in Table 1.

Performance was measured by profit margin percentage, providing a broad and relevant measure of an organisation's financial health, capturing key aspects like efficiency and productivity (Alsyouf, 2007), without being overly influenced by the organisation's size (Andriana & Anisykurlillah, 2019). We chose a financial performance indicator that is broad enough to capture a comprehensive take on performance. For

Table 1
Items capturing firm innovativeness and open innovation using Likert scale.

	Question
Innovativeness	1. When launching new products or service, our company is usually first on the market. 2. Our clients often evaluate our products or service as highly creative. 3. Our products and services are competitive with others that are on the market. 4. We constantly emphasise development of innovative or patent products. 5. Compared to competitors, our company introduced more innovative products/services in the past three years. 6. We are capable of quick response to market needs that demand developing new products. 7. We are constantly adjusting the shape of our own products/services in order to be competitive for fast changing and developing markets. 8. Our company is flexible in developing new products/services based on wishes and orders of customers. 9. We are continuously improving existing products/services and thereby we raise quality of new ones.
Open innovation	1. In developing new products/services we also include customers/final users/clients. 2. Our products/services are usually developed based on client's wishes or needs. 3. We include our clients in testing new products/services. 4. We believe that use of external knowledge/technology importantly impacts on innovation of the company.

Items source: Rangus et al. (2016); Škerlavaj et al. (2010).

example, measuring revenue alone would not be appropriate, as revenue is too closely tied to the size of the organization. Profit margin percentage captures profitability, but also efficiency, is comparable across industries and countries, provides insights into the cost structure and sustainability, while signalling to other stakeholders. ***Size*** was assessed by the number of employees in a given organisation. This is used as a control variable because the size of an organisation is positively correlated with the ability to develop and absorb new knowledge within an organisation (Forés & Camisón, 2016). Furthermore, the size of an organisation is positively correlated with innovation activity, and innovation activity is related to the performance of an organisation (Hsu et al., 2015; Leal-Rodríguez et al., 2015).

Results

Descriptive statistics, validity and reliability

In terms of size, the smallest organisations in the sample analysed are from Croatia, with a median of 8 employees, and the largest are from Austria, with 25 employees. The youngest organisations included in our analysis are from Austria with a median of 20 years, while the oldest are from Slovenia with 25 years. Table 2 shows the responses related to educational heterogeneity in R&D. The most valid answers came from Slovenia - 53, the fewest from –Austria - 46.

Table 3 demonstrates the reliability and validity statistics. It shows the mean, standard deviations, and Pearson correlation coefficients for all constructs in our tested model and Cronbach's Alphas for innovation and open innovation measurement scale.

To test for construct validity and factor structure of the constructs captured with multi-item scales, we applied confirmatory factor analysis (CFA) using AMOS software (version 21). The expected two-factor solution of our focal variables (firm innovativeness and open innovation) demonstrated good fit with the data (chi-square (56) = 229.133, CFI = 0.917, NFI = 0.881, RMSEA = 0.095) .[1]

Hypotheses testing

To test our hypotheses, we used the SPSS software package. First, we analyse the relationship between educational heterogeneity in R&D and organisational performance (H1a) and innovativeness (H1b) through linear regression. In addition, we analyse mediation by innovativeness (H2), moderation by open innovation (H3a), and then the model of moderated mediation (H3b). We followed standard procedures for analysing these mediation, moderation and moderated mediation using the add for SPSS software package - PROCESS macro Model 1, Model 4, and Model 7 (Hayes & Preacher, 2014). In order to increase the robustness of the moderation, mediation and moderated mediation results, we used the Huber-White method (Huber, 1967; White, 1980).

Table 4 shows the results of our analyses. We used linear regression to test the relationship between educational heterogeneity in R&D and organisational performance (H 1a). Hypothesis 1a is not confirmed because the results are not statistically significant (constant = 9.495; β = 1.178). To test the relationship between educational heterogeneity in R&D and innovativeness (H 1b), we also used linear regression. The results are highly statistically significant (constant = 3.293; β = 0.598) and we can support hypothesis 1b.

To test Hypothesis 2, we used Model 4 in PROCESS macro from Hayes and Preacher (2014). The direct effect of educational heterogeneity on organisational performance is not statistically significant (p = .6138). The mediated relationship between educational heterogeneity in R&D and organisational performance, where innovativeness is the mediator, is statistically significant and positive (indirect effect = 2.0462 and its confidence interval excludes zero: LLCI = 0.5266; ULCI = 3.8254), we can support hypothesis 2 and conclude that there is a full indirect relationship, with an important role of innovativeness as a mediator.

To test hypothesis 3a, we used Model 1 from Hayes and Preacher (2014). The relationship between educational heterogeneity in R&D and innovativeness, moderated by open innovation, is statistically significant at lower levels of open innovation, but not at levels of the moderator higher then 4.1405, as attested by the Johnson-Neyman significance region, even though the confidence interval includes zero. When educational heterogeneity in R&D is present, open innovation has a lower effect on innovativeness than in the case of educational homogeneity (coefficient = −0.2601 and its confidence interval include zero: LLCI = −0.5375; ULCI = 0.0173), partially supporting hypothesis 3a.

Furthermore, Model 7 of moderated mediation in PROCESS macro (Hayes & Preacher, 2014) showed that the relationship between educational heterogeneity and organisational performance through innovativeness, moderated by open innovation, is statistically significant and negative at lower levels of open innovation, but not at levels of the moderator higher then 4.1405, as defined by the Johnson-Neyman significance region, even though the confidence interval includes zero (index = −0.8834 and its confidence interval includes zero: LLCI = −2.4193; ULCI = 0.0773). This finding indicates that hypothesis 3b is partially supported.[2]

Fig. 2 reveals how the different levels of open innovation are related to innovativeness. The red line shows the relationship in the case of educational heterogeneity. The blue line represents the relationship in the case of educational homogeneity. We can interpret that the change in open innovation has a greater impact on innovativeness when there is educational homogeneity in the R&D teams than lower heterogeneity, as attested by a significant difference in slopes. However, when there is educational heterogeneity in R&D teams and a low level of open innovation, organisations achieve higher innovativeness than when there is educational homogeneity in R&D teams.

Table 2
The educational heterogeneity of R&D by country.

	Slovenia	Austria	Croatia	Total
YES	20	19	13	52
NO	33	27	39	99
Valid	53	46	52	151

Discussion and conclusion

Interpretation of findings

The extant literature was quite clear to establish that innovativeness is generally positively related to organisational performance (Geroski et al., 1993; Leal-Rodríguez et al., 2015; Rajapathirana & Hui, 2018). A substantial body of research supports the value of heterogeneity within teams and organisations, suggesting that diversity is a key driver of innovation, productivity, and enhanced organisational outcomes (Díaz-García et al., 2013; Hoisl et al., 2017; Mohammadi et al., 2017; Niebuhr, 2010; Parrotta et al., 2014; Phillips, 2014; Reagans & Zuckerman, 2001; Tang & Ye, 2015). Researchers widely agree that embracing heterogeneity fosters a more innovative and high-performing organisational environment.

On the other hand, some researchers point out that we need to be careful with employee heterogeneity, as too much heterogeneity can

[1] Within-construct item (for example, items corresponding to the innovativeness scale with other items pertaining to the same scale) residuals were allowed to correlate.

[2] All results of hypotheses also hold with the inclusion of control variables of firm age and country.

Table 3
Descriptive statistics, correlations and reliability indices.

	Mean	Std. Deviation	Size	Innovativeness	Open innovation	Profit margin	Educational structure
Size	153.65	872.293	(-)				
Innovativeness	3.4989	0.80644	0.123	(0.887)			
Open innovation	3.3245	1.04912	0.096	0.541**	(0.805)		
Profit margin	9.9	11.193	0.103	0.241**	0.047	(-)	
Educational structure	0.34	0.477	−0.02	0.354**	.235**	0.05	(-)

** Pearson correlation is significant at the 0.01 level (2-tailed); Coefficient alphas are on the diagonal in parentheses.

Table 4
Summary of results.

	Linear regression; Outcome variable: PERFORM- ANCE	Linear regression; Outcome variable: INNOVATI- VENESS	Model 4 (mediation); Outcome variable: INNOVATI- VENESS	Model 4 (mediation); Outcome variable: PERFORMANCE	Model 1 (moderation); Outcome variable: INNOVATIVENESS	Model 7 (moderated mediation); Outcome variable: PERFORMANCE
Constant	9.495 (1.127)**	3.293 (0.076)**	3.269 (0.0827)**	−1.8424 (3.9403)	1.9278 (0.2459)**	−1.8424 (3.9403)
Educational heterogeneity in R&D	1.178 (1.921)	0.598 (0.13)**	0.6024 (0.116)**	−0.8202 (2.0177)	1.3314 (0.5273)	−0.8202 (2.0177)
Innovativeness				3.3965 (1.2936)**		3.3965 (1.2936)**
Size (control)			0.0001 (0.0000)**	0.0009 (0.0019)	0.0001 (0.0000)**	0.0009 (0.0019)
Open innovation (moderator)					0.4299 (0.075)**	
Educational heterogeneity in R&D x Open innovation (moderator)					Coefficient se −0.2601 0.1404 LLCI ULCI −0.5375 0.0173	
Moderation of Open innovation on Educational heterogeneity in R&D -> Innovativeness					Open-inovation Effect se 2.2500 0.7462 0.2284 3.5000 0.4211 0.1135 4.5000 0.161 0.1605 LLCI ULCI 0.2948 1.1977 0.1969 0.6454 −0.1561 0.4782	Open-inovation Effect se 2.2500 0.7462 0.2284 3.5000 0.4211 0.1135 4.5000 0.1615 0.1605 LLCI ULCI 0.2948 1.1977 0.1969 0.6454 −0.1561 0.4782
Moderator value(s) defining Johnson-Neyman significance region(s)					Value % below 4.1405 78.8079 % above 21.1921	Value % below 4.1405 78.8079 % above 21.1921
Indirect effect: Educational heterogeneity in R&D -> Innovativeness -> Performance				Effect BootSE 2.0462 0.8544 BootLLCI BootULCI 0.5266 3.8254		Open-inovation Effect BootSE 2.2500 2.5346 1.3284 3.5000 1.4303 0.6756 4.5000 0.5469 0.5802 BootLLCI BootULCI 0.3660 5.5496 0.2865 2.8947 −0.5789 1.7934
Index of moderated mediation: Open innovation (moderator)						Index BootSE −0.8834 0.6418 BootLLCI BootULCI −2.4193 0.0773
F	0.376	21.289	18.8035	2.9914	21.6728	2.9914
df	(1, 149)	(1, 149)	(2, 148)	(3, 147)	(4, 146)	(3, 147)
R^2	0.003	0.125	0.142	0.0646	0.3736	0.0646

*$p < .05$; **$p < .01$; abbreviations: Bootstrap lower limit confidence interval (BootLLCI), Bootstrap upper limit confidence interval (BootULCI), Bootstrap Standard Error (BootSE).

have negative consequences (Hoisl et al., 2017; Vera Nemanich et al., 2016; Mohammadi et al., 2017; Bellini et al., 2013; Niebuhr, 2010, Tang & Ye, 2015). As a counterpoint to this assertion, using an open innovation model has also been shown to generally be beneficial for organisations. It brings heterogeneity to organisations and helps solve problems faster and at lower cost (Enkel et al., 2009).

Open innovation is generally positively related to the innovativeness and financial performance of organisations (Cheng & Huizingh, 2014; Faems et al., 2010). However, overuse of open innovation has also been shown to have potentially negative effects (Laursen & Salter, 2006). To the best of our knowledge, there have been no studies examining the boundary conditions for the effects of open innovation with regards to R&D heterogeneity, particularly cognitive (educational) diversity. We hypothesised that educational heterogeneity in R&D and in the use of the open innovation model is desirable and positively related to firm performance via innovativeness, as shown in Fig. 1.

We found no support for a positive direct relationship between educational heterogeneity in R&D and organisational (financial) performance. However, we found support for the indirect relationship between educational heterogeneity in R&D and organisational performance through innovativeness as a mediator. We also supported the positive relationship between educational heterogeneity in R&D and innovativeness. In addition, we also confirmed the importance of open innovation as a moderator of the relationship between educational

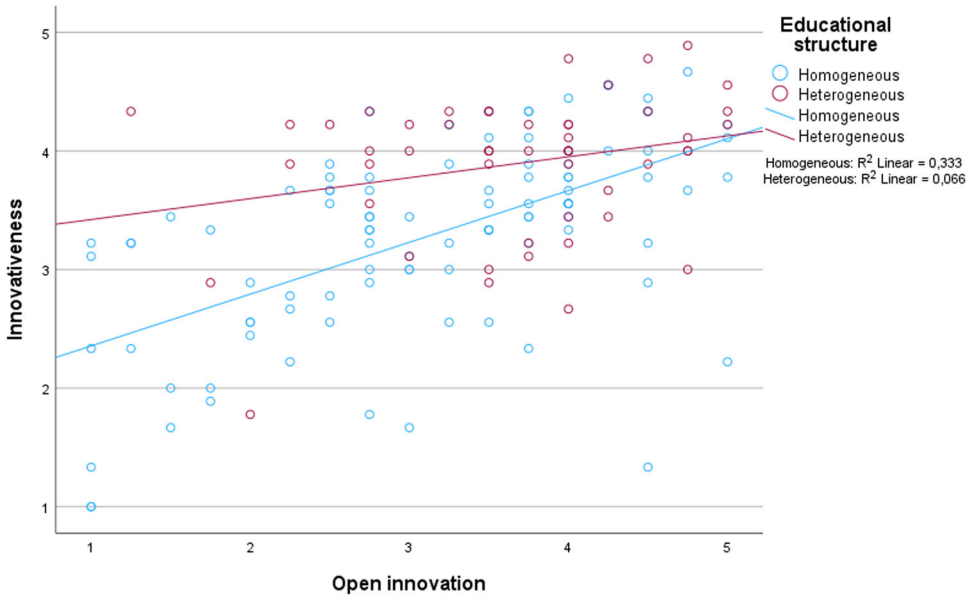

Fig. 2. Relationships between R&D educational heterogeneity, open innovations and organisational innovativeness.

heterogeneity in R&D and innovativeness, especially at a lower level than 4.1405 of open innovation. That is shown in Fig. 2. Finally, we also found statistical significant support for hypothesis 3b at a lower level than 4.1405 of open innovation. The logic behind our research model presented in Fig. 1 is thus supported except for the direct relationship between educational heterogeneity in R&D and organisational performance.

Based on these results, we can confirm the important role of innovativeness as a mediator of the relationship. Our results are mostly consistent with the findings of other authors. Østergaard et al. (2011) pointed out the importance of educational heterogeneity for organisational innovativeness. Moreover, Leal-Rodríguez et al. (2015) discovered a positive correlation between innovativeness and organisational performance. Geroski et al. (1993) and Rajapathirana and Hui (2018) also found similar results.

With hypothesis 3a, we add open innovation as a moderator for the relationship between educational heterogeneity in R&D and innovativeness. When organisations have low educational heterogeneity in R&D, open innovation contributes to the highest levels of performance (index = −0.8834 and its confidence intervals include zero: LLCI = −2.4193; ULCI = 0.0773). Our results do not support H 3a and H 3b at lower levels of open innovation, which can also be supported by the existing literature.

Chesbrough (2003) found that open innovation brings in external knowledge and ideas and increases value. In addition, Enkel et al. (2009) found that working with organisations that are not in the same field means that they have different profiles of employees with different knowledge and experience. They also noted that open innovation will gain momentum by helping organisations solve their problems more quickly, efficiently, and cost-effectively. This means that when there is a lower degree of heterogeneity in R&D, "new external" knowledge (open innovation) and ideas have a greater impact than when there is a higher level of internal heterogeneity. From this perspective, our results are consistent with researchers who support the idea of the interplay between heterogeneity and innovativeness in fostering performance (Dahlander et al., 2016; Dahlin et al., 2005; Hoisl et al., 2017; Niebuhr, 2010; Tang & Ye, 2015).

Theoretical contributions

The first contribution of this study lies in advancing our understanding of how educational heterogeneity within R&D teams interacts with innovation to influence organisational performance. We extend the study by Díaz-García et al. (2013), which explained the relationship between gender diversity in R&D and innovativeness, by adding a new important diversity viewpoint-education in R&D. In addition, our study analysed specific educational heterogeneity in R&D with an item directly focusing on non-technical educational backgrounds. This strong focus on non-technical-and-life-science educational backgrounds in particular complements the study by Østergaard et al. (2011), who examined different types of heterogeneity in relation to innovativeness, including heterogeneity in education, but not educational heterogeneity in R&D.

Moreover, we found support for a positive relationship between innovativeness and organisational performance, as Geroski et al. (1993); Østergaard et al. (2011); Rajapathirana and Hui (2018). In contrast to Herrings (2009) study, which found a positive relationship between racial and gender diversity and organisational financial performance, and Grund and Westergaard-Nielsen (2008) study, which found a relationship between age heterogeneity and organisational performance, we found no direct relationship between educational heterogeneity in R&D and organisational performance. However, we found an indirect positive relationship between educational heterogeneity and organisational performance through innovativeness as a mediator. This confirms the importance of innovativeness as an important missing link when considering the relationship between educational heterogeneity in R&D and organisational performance and provides additional support for the research stream linking organisational innovation and firm performance (Camisón & Villar-López, 2014; Mazzanti et al., 2006).

The second contribution of this paper relates to the exploration of a boundary condition of open innovation. We focus on the concept of open innovation, which has previously been found to be positively associated with organisational innovativeness (Cheng & Huizingh, 2014; Chesbrough, 2003; Enkel et al., 2009; Garriga et al., 2013; Laursen & Salter, 2006; Lettl et al., 2006; Parida et al., 2012; Piller & Walcher, 2006) and performance (Faems et al., 2010). Our findings are consistent with these studies in exploring the positive effects of open innovation. We extended the listed studies by showing that open innovation is an important moderator of the relationship between educational heterogeneity in R&D and innovativeness. More specifically, innovativeness is lower in educationally homogeneous R&D than in educationally heterogeneous R&D when the level of open innovation is lower, but the impact of open

innovation is stronger in educationally homogeneous R&D as shown in Fig. 2.

Moreover, open innovation is more important in education-homogeneous R&D than in heterogeneous R&D teams, illustrating an interesting trade-off between internal and external sources of innovative ideas. We have thus highlighted two paths that R&D teams can take in terms of composition that lead to organisational innovativeness and performance: an internal one that leverages sources of innovation within heterogeneous R&D teams, and an external path that combines homogeneous R&D teams with external sources. When R&D team members have similar educational backgrounds, their problem-solving approaches, methodologies, and perspectives are often aligned, which can limit the generation of novel ideas internally (Cox & Blake, 1991). In this context, seeking external sources of innovation becomes essential to introduce new concepts, technologies, and practices that the team might not have otherwise considered. By engaging in open innovation, such as collaborating with external partners, customers, or research institutions, education-homogeneous teams can access a broader pool of knowledge and diverse perspectives, supplementing their internal capabilities (Chesbrough, 2003).

On the other hand, education-heterogeneous R&D teams bring together individuals with varied educational backgrounds, experiences, and areas of expertise. This internal diversity naturally fosters a richer environment for creativity and idea generation, as team members can draw on a wide range of knowledge bases and problem-solving approaches (Williams & O'Reilly, 1998). In these teams, the internal exchange of ideas and cross-pollination of concepts can lead to innovative solutions without as much reliance on external inputs. The internal diversity within the team can serve as a catalyst for innovation, reducing the need to look outside for new ideas. This finding represents a contribution to the existing body of knowledge on heterogeneity, innovativeness, and performance by demonstrating and further specifying the role of the interplay between educational heterogeneity of R&D employees and open innovation on innovativeness and organisational performance.

Practical implications

Based on our study, we can recommend organisations to increase educational heterogeneity in R&D. It leads to higher innovativeness (Østergaard et al., 2011) and innovativeness is associated with performance (Geroski et al., 1993; Østergaard et al., 2011; Rajapathirana & Hui, 2018). If they cannot increase educational heterogeneity in R&D, they should try to open the organisation to open innovation. With open innovation, organisations can provide the desired heterogeneity of views, new ideas, and knowledge, and increase innovativeness and financial performance.

We have shown that higher levels of open innovation lead to higher levels of innovativeness, which is consistent with the findings of Laursen and Salter (2006); Lettl et al. (2006), Parida et al. (2012), and Piller and Walcher (2006). The relationship is more positive in the case of homogeneous education than in the case of heterogeneous R&D. However, in the case of low R&D heterogeneity, we recommend that organisations use open innovation as a way to bring new ideas and knowledge into the organisation. They can do this by shaping the organisational culture to facilitate open innovation activities in the sense of being more open to external sources of ideas (Mortara & Minshall, 2011). They should start to cooperate on ideation activities with their suppliers (Emden et al., 2006), customers (West & Lakhani, 2008), universities (Perkmann & Walsh, 2007), and other stakeholders. When gathering new ideas from external sources, it is important to establish an evaluation system for these ideas as well as a knowledge management system that can ultimately lead to a continuous process of adopting and implementing open innovations (Chiaroni et al., 2011).

Limitations and recommendations for future research

Like other researchers, we ran into limitations in accessing data. The complexity of the problem is also a limitation, as the field is still much unexplored. This complexity implies that rather time-consuming research is required. In addition, one of the fundamental limitations is that all the data in the survey are collected based on the organisations themselves filling out anonymous questionnaires, which is especially problematic for the data on the organisations' performance. Organisations, whether due to mistrust or other factors, do not necessarily provide genuine responses. This may have led to biased results.

One key limitation of measuring R&D educational heterogeneity with a single binary question, which represents an oversimplification of the diversity of educational backgrounds. This approach does not capture the nuances or range of disciplines beyond the binary response. It assumes that educational contributions can be sufficiently categorized as "other" without distinguishing between fields like social sciences, humanities, or applied sciences, each of which could uniquely impact innovation. Moreover, it neglects the varying levels of expertise within those non-scientific disciplines, treating all non-natural sciences education as a monolithic category. This lack of granularity could lead to an incomplete understanding of the true interdisciplinary nature of the R&D team, potentially obscuring important insights into how educational heterogeneity drives research outcomes and innovation. We thus recommend future research to tackle this issue.

Further limitations of the study include the sample selection procedure and the response rate. The sample selection process was not entirely uniform: in Slovenia and Croatia, companies were included without any restriction criteria, whereas in Austria, the sample was limited to companies with >10 employees. The response rate for fully completed surveys was relatively low and varied significantly across countries, with Slovenia at 2.822 %, Croatia at 0.46 %, and Austria at 0.125 %. These factors, while unfortunately typical in firm-level empirical research in the business field, may pose challenges to the generalizability of the results.

Another limitation is the bias associated with obtaining data from a cross-sectional survey and from only one source. Therefore, it is not possible to make a statement with certainty about the causality of the observed relationships - the opposite effect is also possible. We therefore propose to use the plan of longitudinal research and linking primary data with secondary data on the performance of organisations from accessible databases. In this way, actual value added per employee, profit, revenue, and other performance indicators could be examined.

For future research, we recommend including new variables and examining other heterogeneities in R&D, such as gender, age, experience, race, ethnicity, and others, and examining the interplay between them in terms of innovativeness and performance, moderated by open innovation. This would add to the body of knowledge on this topic. Development and innovativeness are known to be the foundation of progress and prosperity. Therefore, we believe that further research in this area is essential, as organisations with this knowledge will be able to be more efficient, innovative and profitable, leading to greater prosperity for society.

Expects data policy

Data available upon request from the first author

CRediT authorship contribution statement

Fabijan Leskovec: Writing – original draft, Visualization, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Matej Černe:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization. **Darja Peljhan:** Project administration.

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